Better Buildings
U.S. DEPARTMENT OF ENERGY

Costs and Energy-Saving Benefits of EIS

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U.S. DEPARTMENT OF ENERGY

Outline

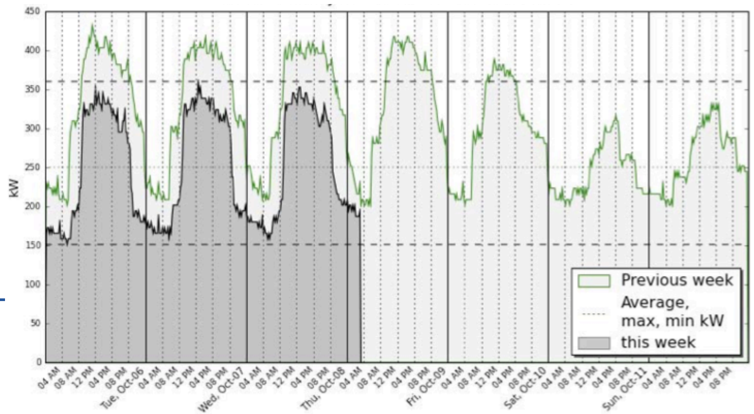
- Motivation and definitions
- Current value proposition and study design
- Energy savings and EIS benefits
- Technology costs and payback
- Conclusions and next steps

Motivation

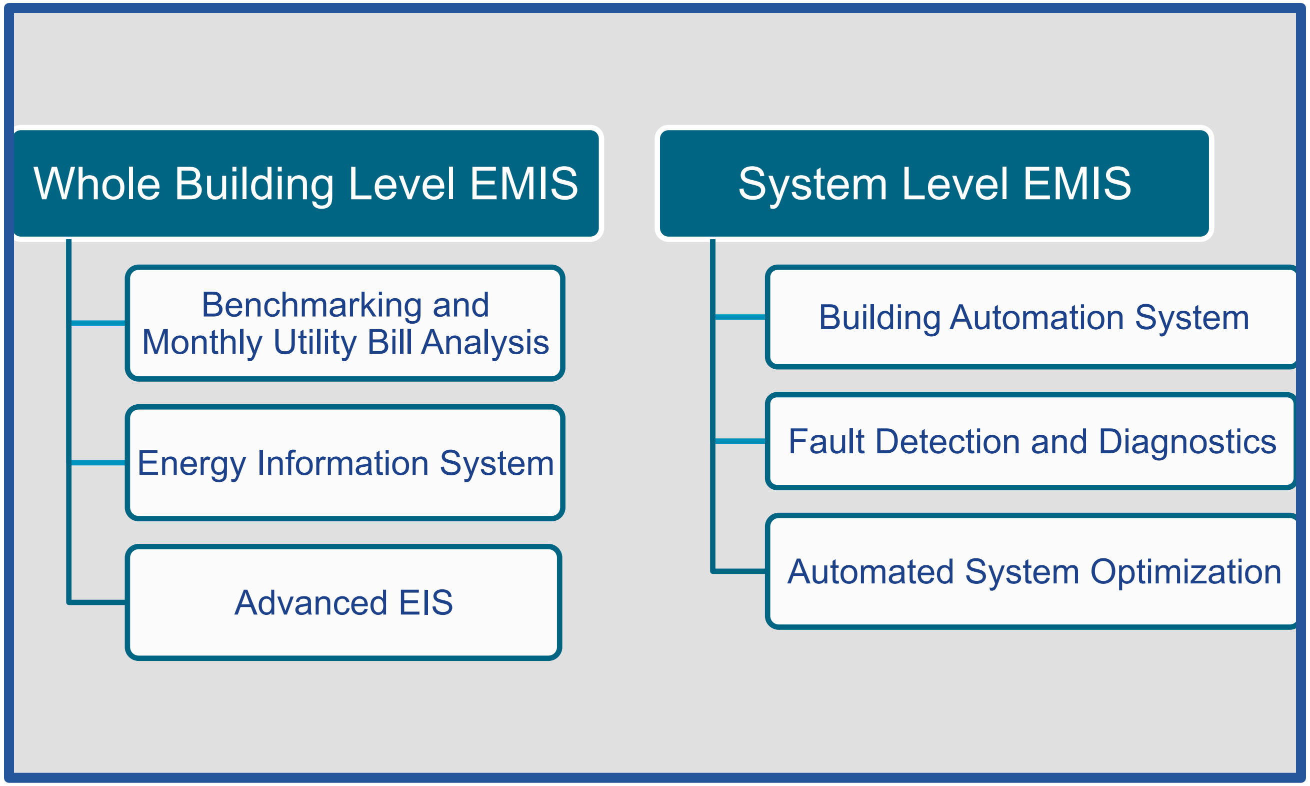
- Energy performance monitoring and reporting has come to the forefront of the national energy dialogue
  - Zero-energy and smart grid initiatives
  - EISA 2007, federal and state labeling and reporting mandates

- Optimal performance requires higher granularity data, more timely analysis than monthly utility bills

- Energy Management Information Systems are a promising family of tools to enable deep savings, yet with exception of BAS, underutilized

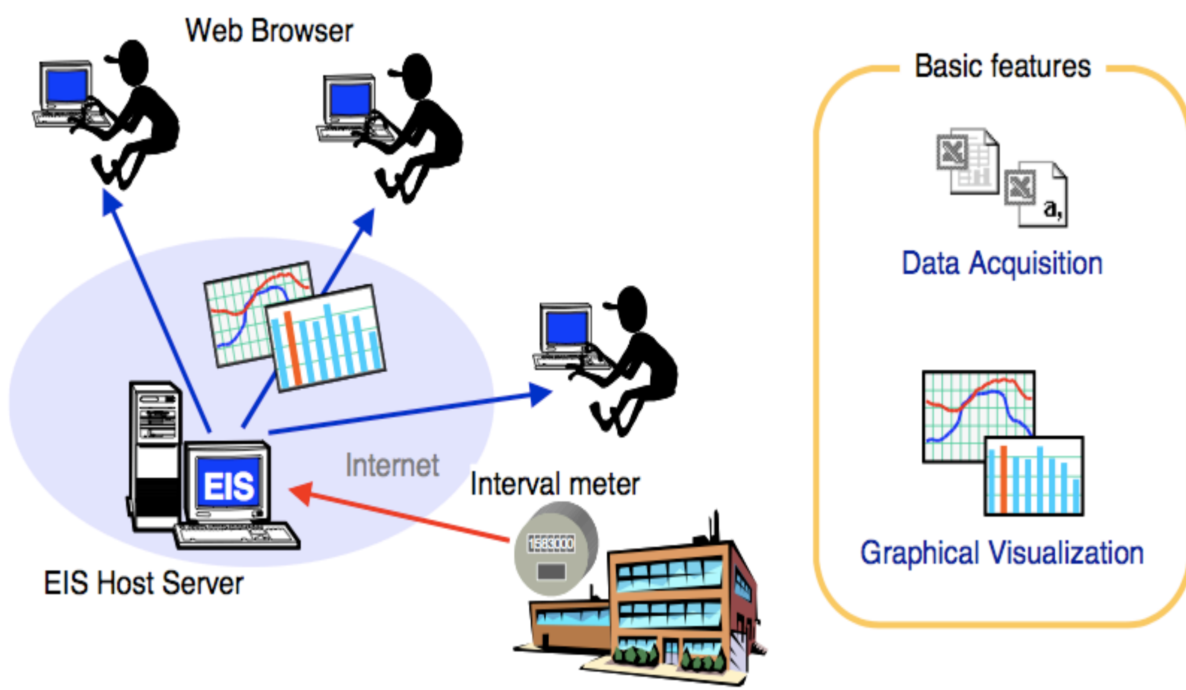


Definitions: EMIS



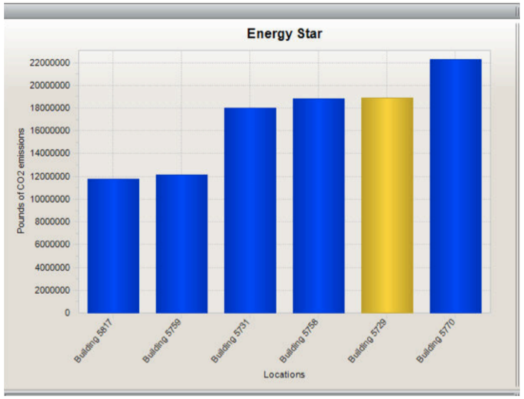
EIS Definition

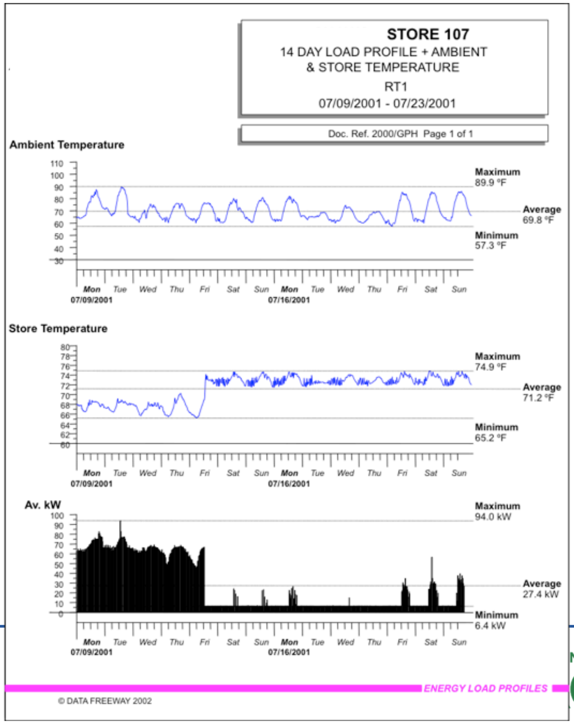
- EIS comprise
  - Software, data acq. hardware, and communication systems
    - To collect, analyze and display building energy information



EIS Definition

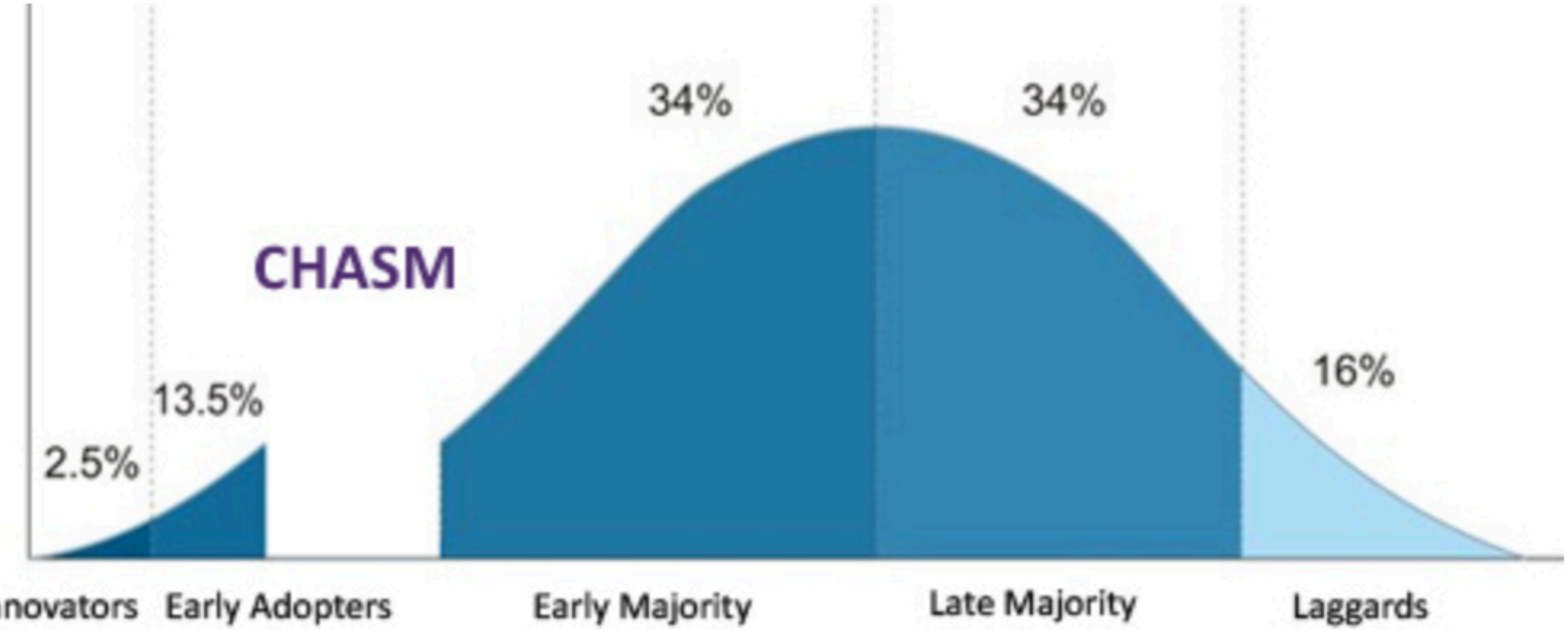
- EIS provide
  - Web-accessible hourly whole-building electric data
  - Graphical/visualization capabilities
  - Automated building energy analyses
- EIS are NOT
  - Most Energy Management and Control Systems (EMCS)
  - Equipment fault detection and diagnostics (FDD)
  - Energy information dashboards
  - Greenhouse gas (GHG) footprint calculators





Study Scope

- This study concerns the value proposition associated with use of EIS and advanced EIS
- EIS still an emerging technology, early stages of adoption



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Promising Technology, Barriers to Adoption

- Growing number of case studies document benefits, but use different metrics, narratives
  - payback, $savings in year 1, % EUI savings, total Btu savings ….

- Currently we can say that EIS
  - Enable savings up to 20% depending on depth of metering, user engagement, ….
  - Cost anywhere from $5K/yr up, depending on extent of software features, # points, configuration needs ….

- Widespread EIS adoption hindered by 2 critical barriers:

  1) lack of information on technology cost, associated energy/cost savings

  2) limited understanding of how to use technology for maximum benefit

Challenges in Quantifying the Value Proposition for EIS

- Information technologies are process tools, *not* equipment
- Savings aren't guaranteed with installation, attribution of benefits confounded by concurrent efficiency activities
  - EIS rarely if ever installed as the sole efficiency measure
  - Typically part of larger efficiency initiatives, E mgt practices

Study Objective, Design

- Conduct a series of targeted case investigations of 20-30 EIS implementations to determine
  - Technology costs, site/campus energy saving trends since adoption of the EIS
  - Technology uses to identify opportunities, realize savings

→ Synthesize the findings from the 20-30 cases

→ Provide foundational information for business case development

Study Questions

- What savings were achieved, and what was the role of the EIS?
- What are technology costs, what are the ranges of those costs, and what are key drivers?
- What are the energy management benefits and best practice uses of EIS?
- Which factors are most strongly correlated with deeper energy savings?
  - Extent of efficiency projects
  - User engagement
  - User empowerment
  - Depth of metering
  - Building performance before EIS installation
  - Length of time EIS is installed

Study Design: Participant Cohort

- Cohort represents diverse EIS solutions, commercial sectors, geographies

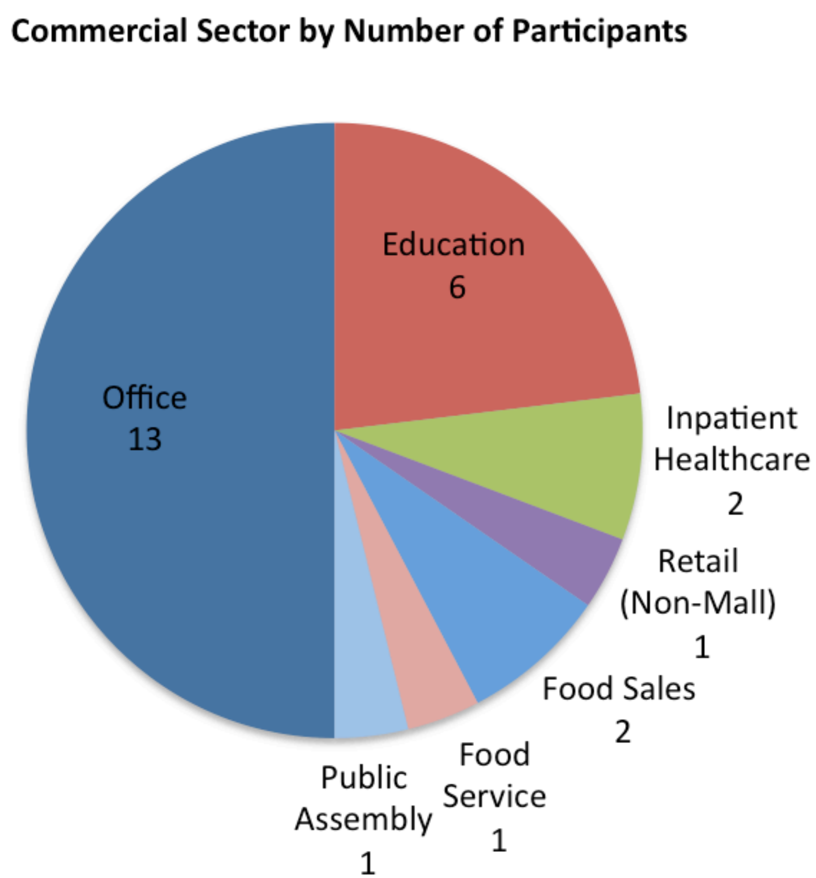
26 organizations including healthcare, educational campuses, office, food service, and retail

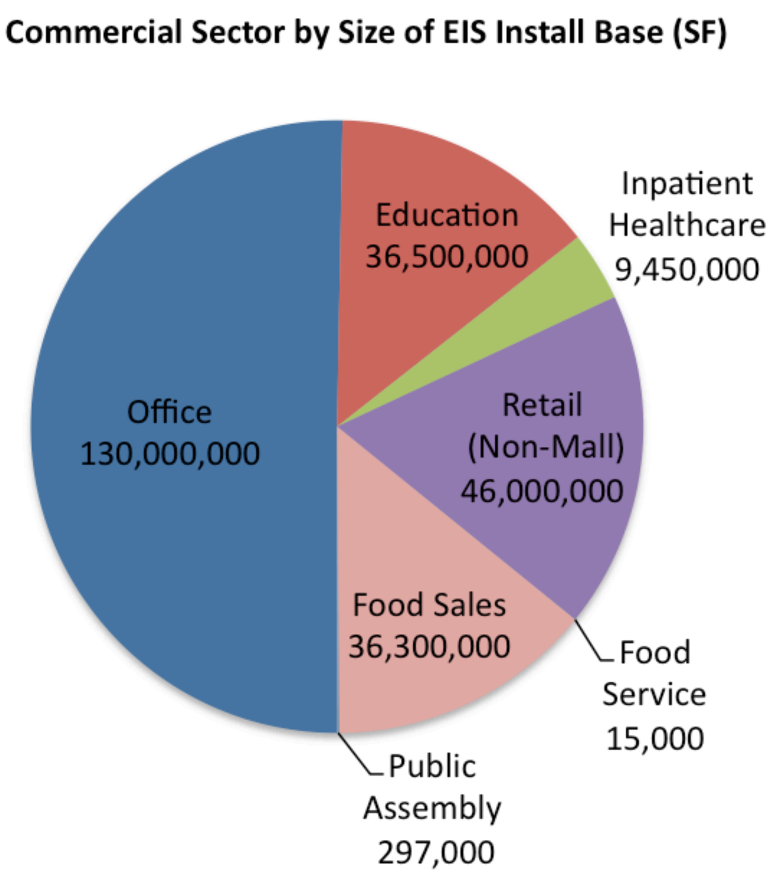
26 EIS implementations, 17 unique commercial EIS solutions

- Energy, project data for 9 portfolios
- Energy, project data for 28 buildings
- EIS procurement cost data for 25 cases

Participant Cohort: Commercial Sectors

- 26 participants with 260 million square feet in a variety of commercial sectors





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ENERGY

Participant Cohort: Cases

Beaverton OREGON

San Ramon Valley Unified School District

UCSB

liberty science center

BRITISH COLUMBIA Ministry of Energy and Mines

BEST BUY

earth rangers

GLENBOROUGH

Wendy's Quality Supply Chain Co-op, Inc. QSCC

LEGACY HEALTH

VORNADO REALTY TRUST

CUSHMAN & WAKEFIELD

Turner

WKU

INTERNATIONAL MONETARY FUND

SUFFOLK COUNTY SEAL NEW YORK FREEDOM AND INDEPENDENCE

SACRAMENTO COUNTY

Microsoft

WHOLE FOODS MARKET

UPMC LIFE CHANGING MEDICINE

Berkeley UNIVERSITY OF CALIFORNIA

Better Buildings U.S. DEPARTMENT OF ENERGY

NewYork-Presbyterian

FOOD LION

McGill

U.S. DEPARTMENT OF ENERGY

Participant Cohort: EIS Vendors

12 vendors referred clients for recruitment to participate in the study

MACH ENERGY

McKinstry

AtSite

Johnson Controls

NOVEDA TECHNOLOGIES

obvius

pulse energy

EFT ENERGY optimizing energy efficiency

lucid™

IBS INTEGRATED Building Solutions

Schneider Electric

NorthWrite

Participant Cohort: Geographic Diversity

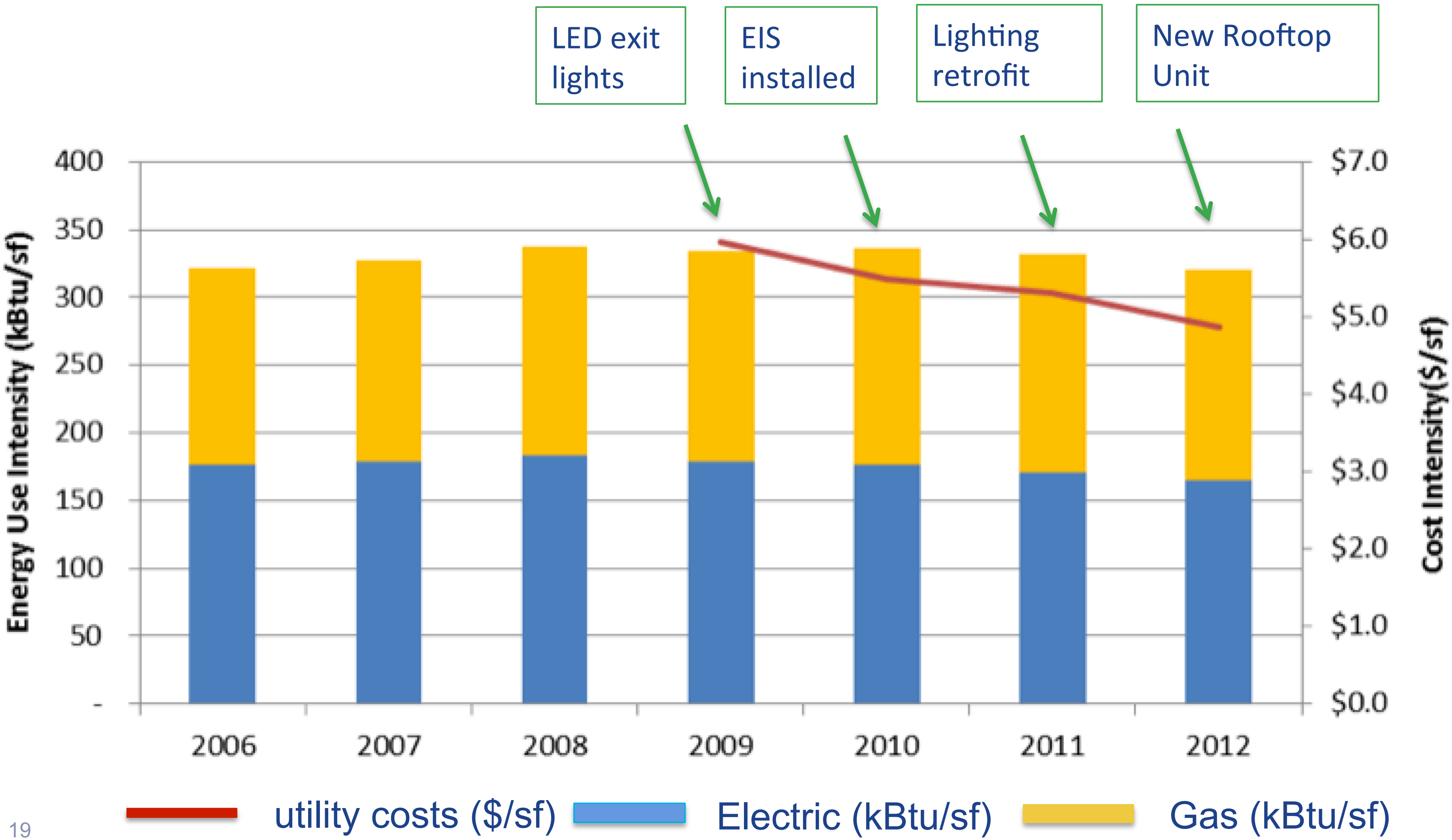
- Energy data was gathered and analyzed for 28 individual building sites from portfolios across the US and Canada

Study Design: Data Collection

- Information collected
  - 90 min interview on technology uses and benefits
  - EIS technology procurement costs
  - Multi-year combined fuels EUI trends for portfolio and/or individual buildings

Technology Costs	
Upfront Costs: Hardware	
	Meter Costs ($)
	Sensor Costs ($)
	Installation Labor Costs ($)
	Other Hardware Costs (specify type and $)
Upfront Costs: Software	
	Per Point Cost ($)
	Per User Cost ($)
	Feature or module Specific cost ($)
	Configuration Labor ($)
	Integration Labor Costs ($)
	Other Software Costs (specify type and $)
Ongoing Costs: Software and Operations	
	Software recurring costs ($)
	Hardware recurring costs ($)
	Other ongoing costs (specify type and $)

Data Collection Example: Year-Over-Year EUI Trends and Efficiency Projects



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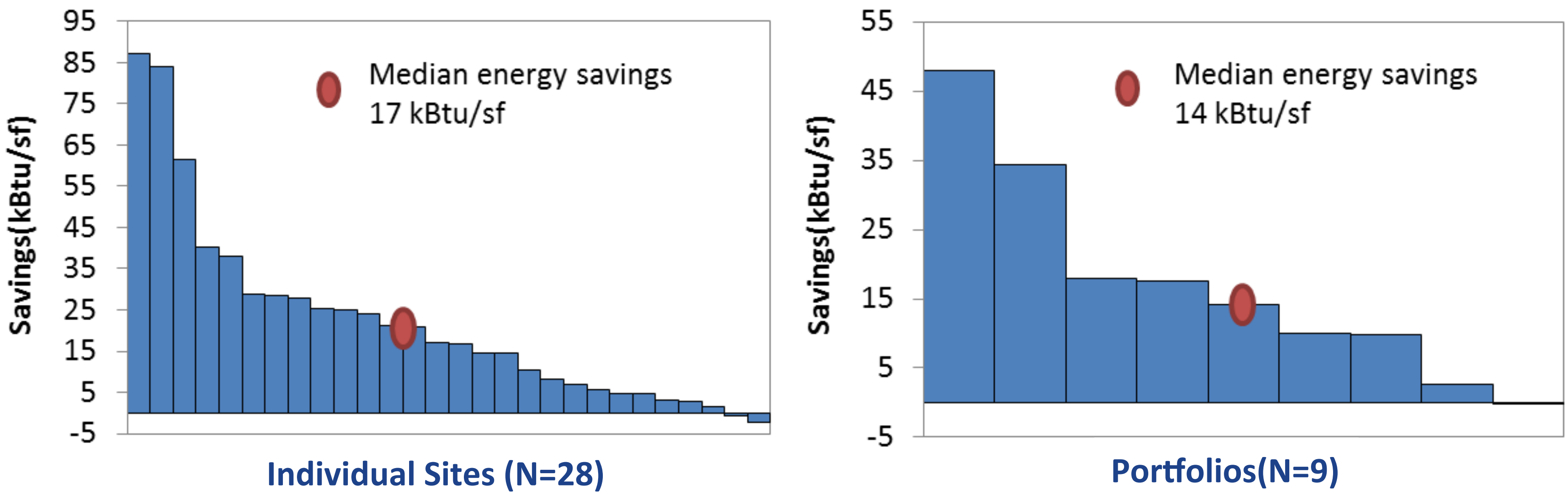
Achieved Energy Savings, Role of EIS

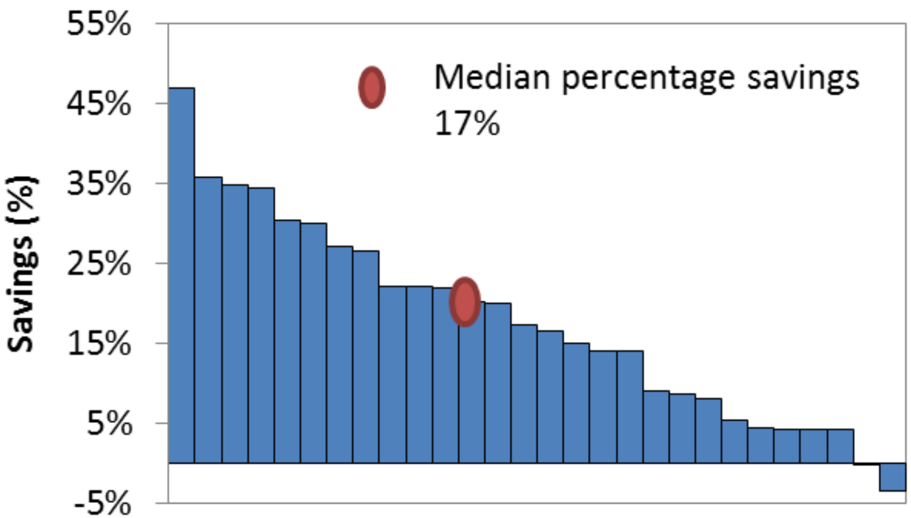
- Median energy savings across cohort, relative to EIS install yr
- 21 of 23 cases said they couldn't achieve this performance w/o EIS

Changes in EUI Since EIS installed

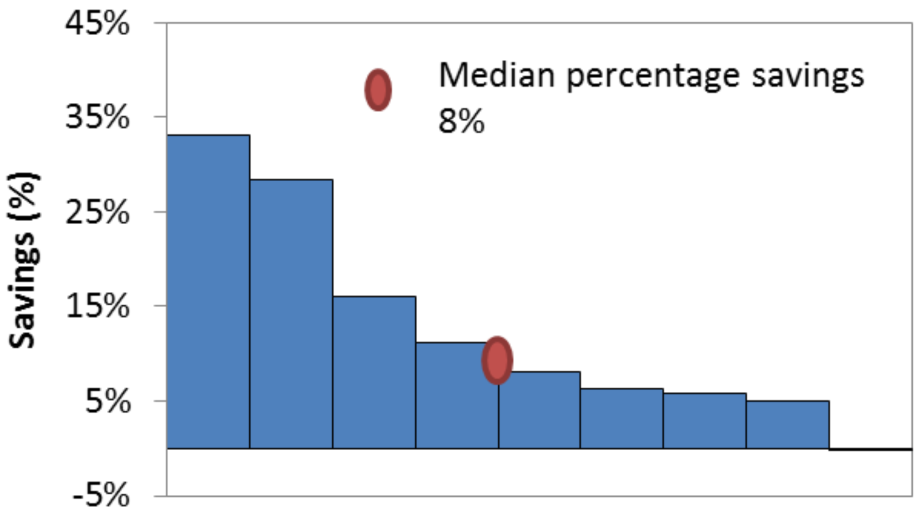


Achieved Savings (Percent)

Percentage Changes in EUI Since EIS installed



Individual Sites (N=28)

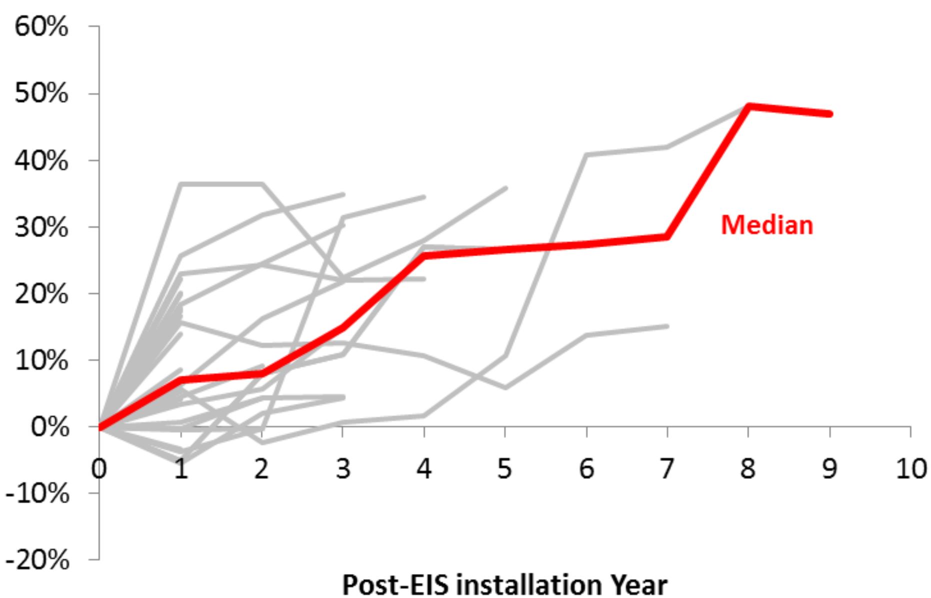


Portfolios (N=9)

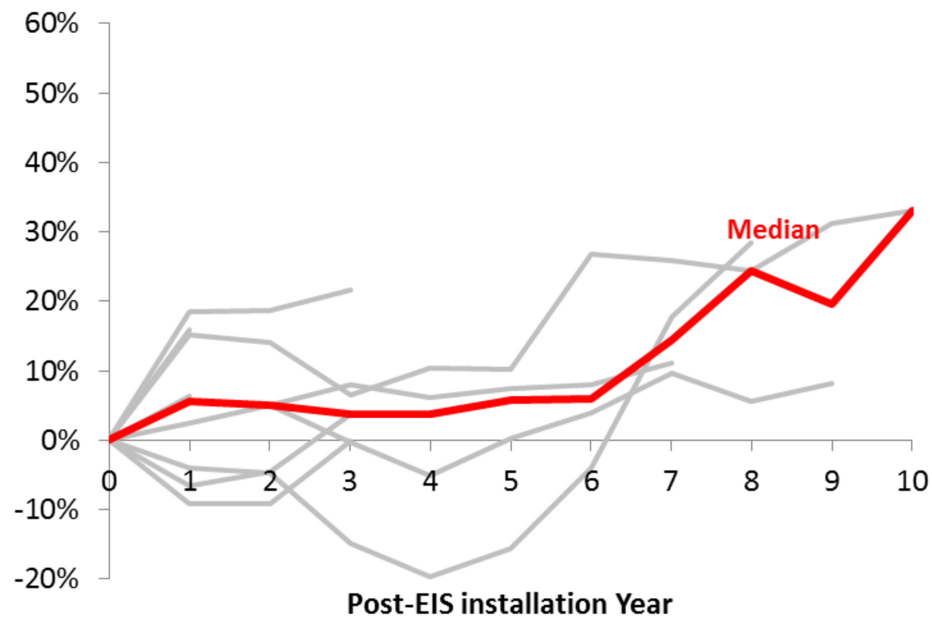
Achieved Savings (Year-by-Year)

% Energy Savings

(Relative to the year prior to EIS installation)



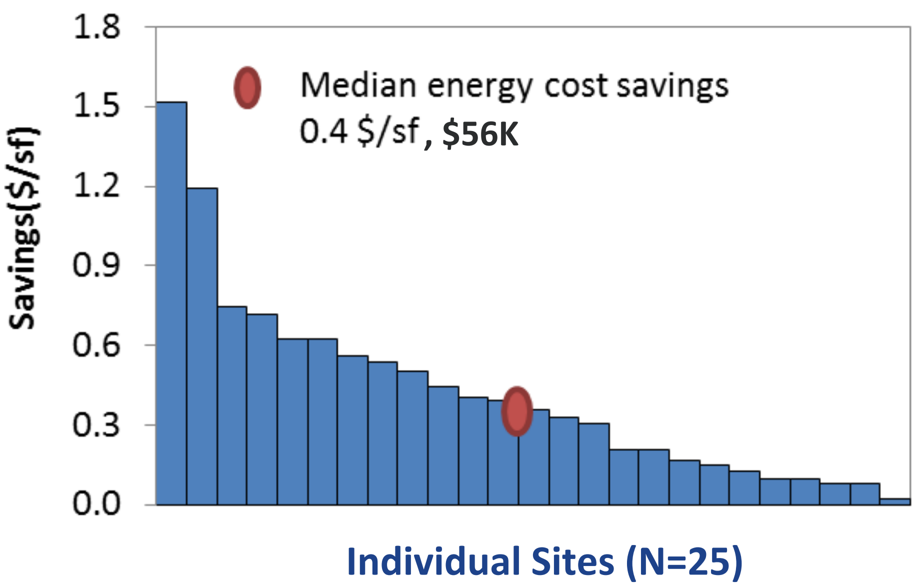
Individual Sites (N=28)

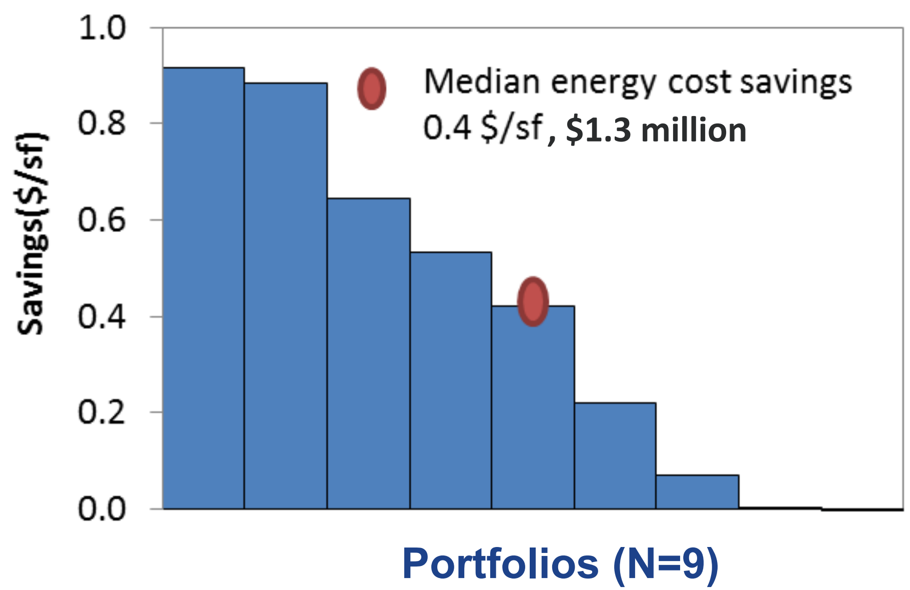


Portfolios (N=9)

Estimated Utility Cost Savings

Changes in Utility Costs Since EIS Installation





Site Level:
Median utility cost savings = $56K

Portfolio Level:
Median utility cost savings = $1.3M

Energy Management Benefits of EIS Use

- Most frequently cited benefits included
  - Identify **operational efficiency opportunities**
    - Scheduling, faults and anomalies, changes in load profile
  - Ability to **track performance, compare** to self and others
  - Monitor peak load and **manage demand charges**
  - Utility **billing validation**
  - **Data** for other custom analyses
  - Information to **ground and set energy goals**

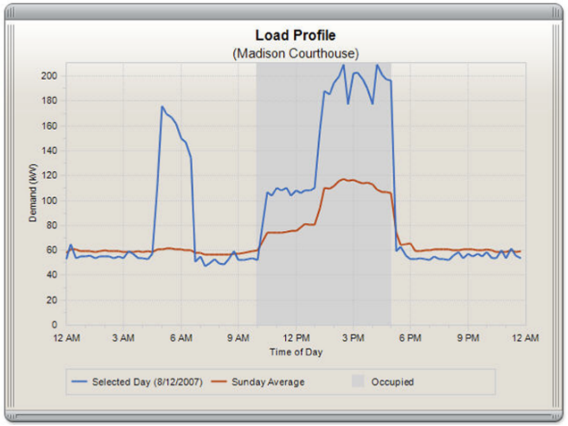
Energy Management Benefits of EIS Use

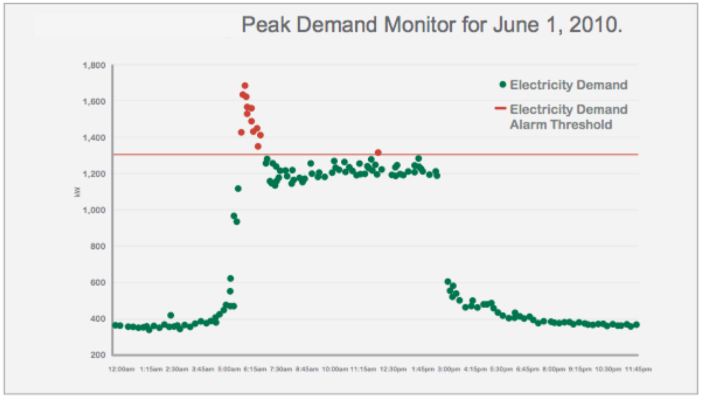
"To realize savings you have to provide tools to enable people to measure their success - you can't put a price tag on that."

"Operators ended up considering it like a game… Everybody in the building got excited, and realized how powerful the tool was, and that it would really be used to save"

Best Practice Uses of EIS

- Load profiling on a regular basis
- Use of automated energy anomaly detection features
- X-Y plots to analyze temperature dependent loads
- Benchmarking to triage for further investigation
- Connection between analyst and operator to effect changes once problems are identified
- Streamlining of utility billing and payment
- Use of data to verify project savings
- Conversion of energy into $, plots and reports





Break for Questions

Midpoint Recap

- Study cohort achieved sizeable energy savings over time
- Most said they couldn’t do it without the EIS
- In addition to EIS, projects and other energy management activities were used to achieve savings
- Factors potentially correlated with deeper savings:
  - building- or organization-specific factors such as EUI before EIS installation, and extent of efficiency projects
  - EIS-related factors such as depth of metering, user engagement, user empowerment, total years of EIS use

Which Factors Correlate Most Strongly with Deeper Energy Savings?

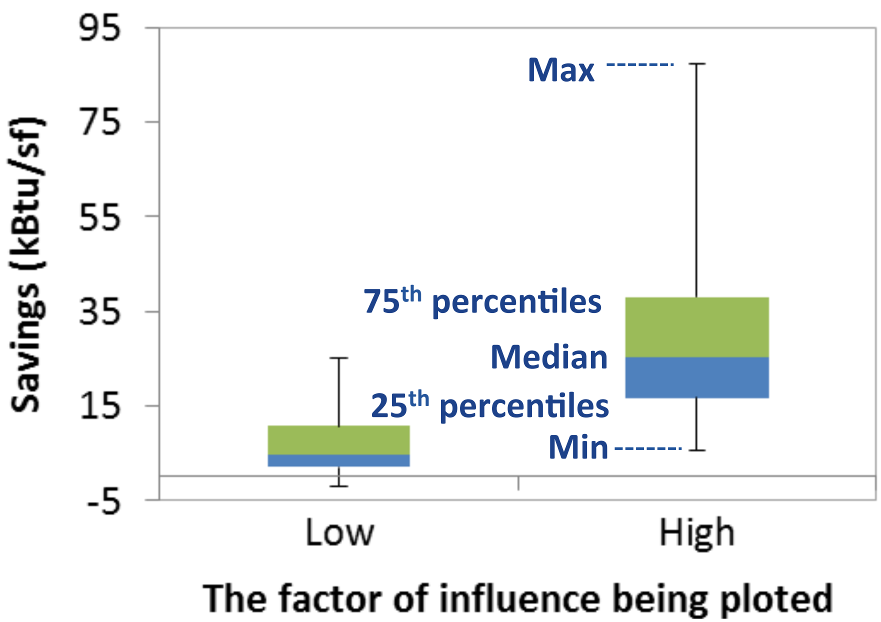
- Three-step analytical process

1. established metrics to characterize the factors as low or high for each case, e.g., *low vs high initial EUI*

2. plotted savings achieved in the *low* vs *high* groups, quantified the differences in group medians

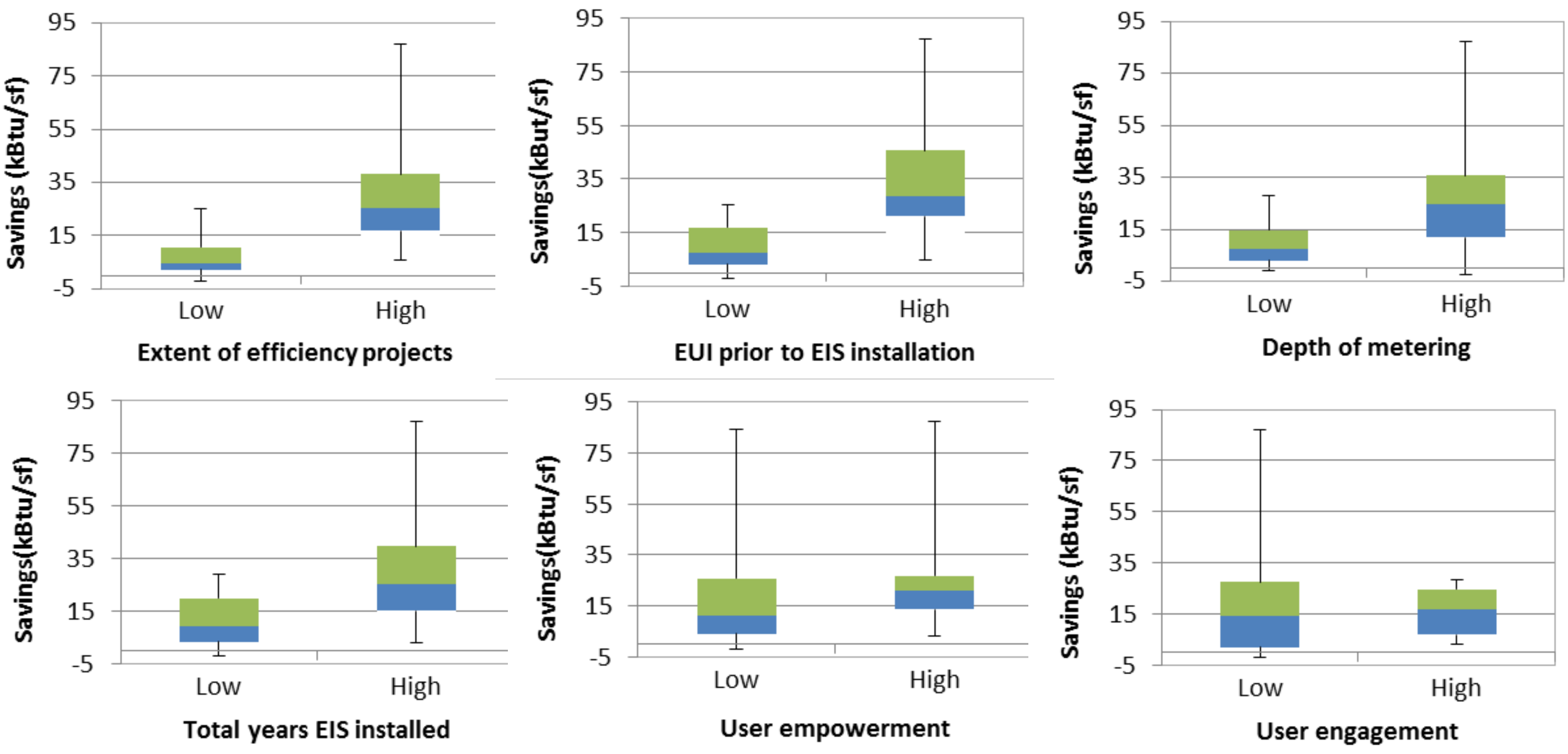
3. investigated statistical significance of the observed differences in achieved median energy savings

Plots of Percentiles, Min/Max, and Median



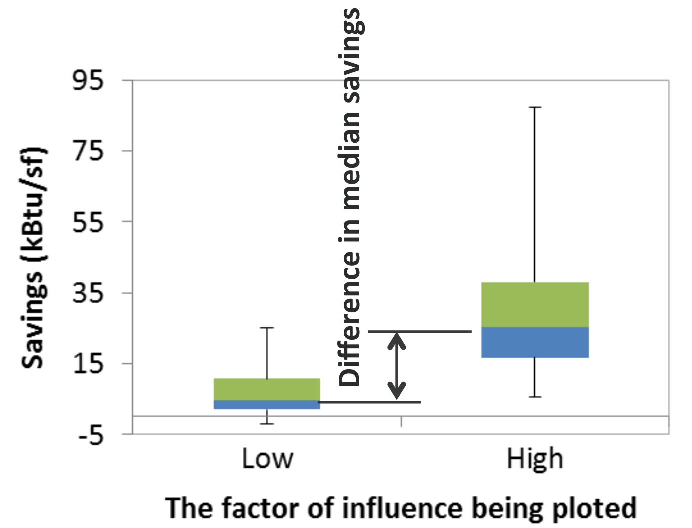
Increased separation/offset between the two groups indicates more distinct differences in achieved energy savings

Achieved Energy Savings and Potential Correlates



Potential Savings Correlates: Difference in Median Savings Between Low and High Groups

Factor	Difference in median savings [kBtu/sf]
Extent of efficiency projects	**21**
EUI prior to EIS installation	**21**
Depth of metering	**17**
Total years EIS installed	**16**
User empowerment	10
Use engagement	2



Statistical Analysis of Size and Significance

- To determine significance and effect size of differences in median savings a single-factor statistical test was conducted

- Wilcoxon Mann Whitney test
  - Non-parametric analog to t-test
  - No assumption that independent variable is normally distributed

- Potential confounding factors
  - Small sample size, self-reported, imperfect data

Wilcoxon-Mann Whitney

- Large effect size, highly significant
  - Extent of projects and EUI prior to EIS installation
- Medium effect size, still pretty significant
  - Depth of metering and total years EIS installed
- Small effect size
  - User engagement and empowerment

Factor	Effect size **(p value)**
Extent of efficiency projects	0.67 **(0.0004)**
EUI before EIS installation	0.65 **(0.001)**
Depth of metering	0.44 **(0.02)**
Total years EIS installed	0.43 **(0.02)**
User empowerment	0.24 **(0.21)**
User engagement	0.11 **(0.58)**

Relative importance of the factors

- Building- and organization-specific factors were largest, most significant
  - Extent of eff. projects provides validity check, by definition large effect
  - Intuitively makes sense that higher savings correlate with initial EUI
- Depth of metering and years EIS in place next strongest correlates
- User engagement and empowerment
  - Not strongly correlated to savings, small effect size
  - Impact of self reporting, bias in self-assessment?
  - Relative differences among cohort not exposing deep overall differences?
  - Larger effect in combination with other factors?
  - Just not as important as the other factors?

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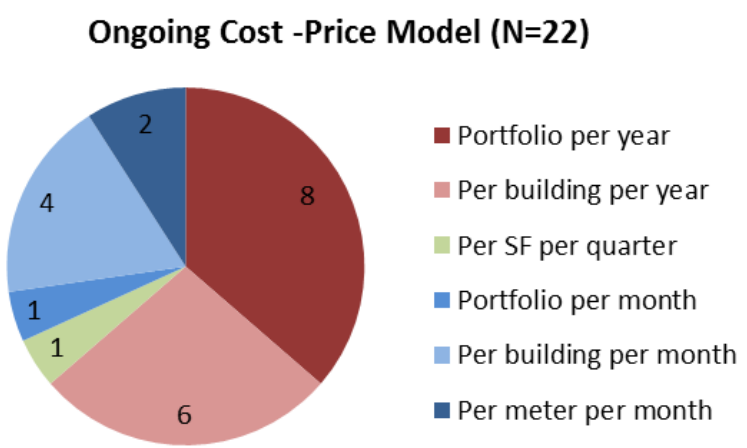
EIS Delivery and Pricing Models

- Most EIS delivered as SaaS offering
  - 5 of 23 cases were on-premises
- Upfront (config, training) and ongoing costs may be assessed
- Ongoing costs
  - Annual fees twice as common as monthly fees
  - Per-building or per-portfolio fees more common than per-meter or per-sf



Summary of EIS Costs

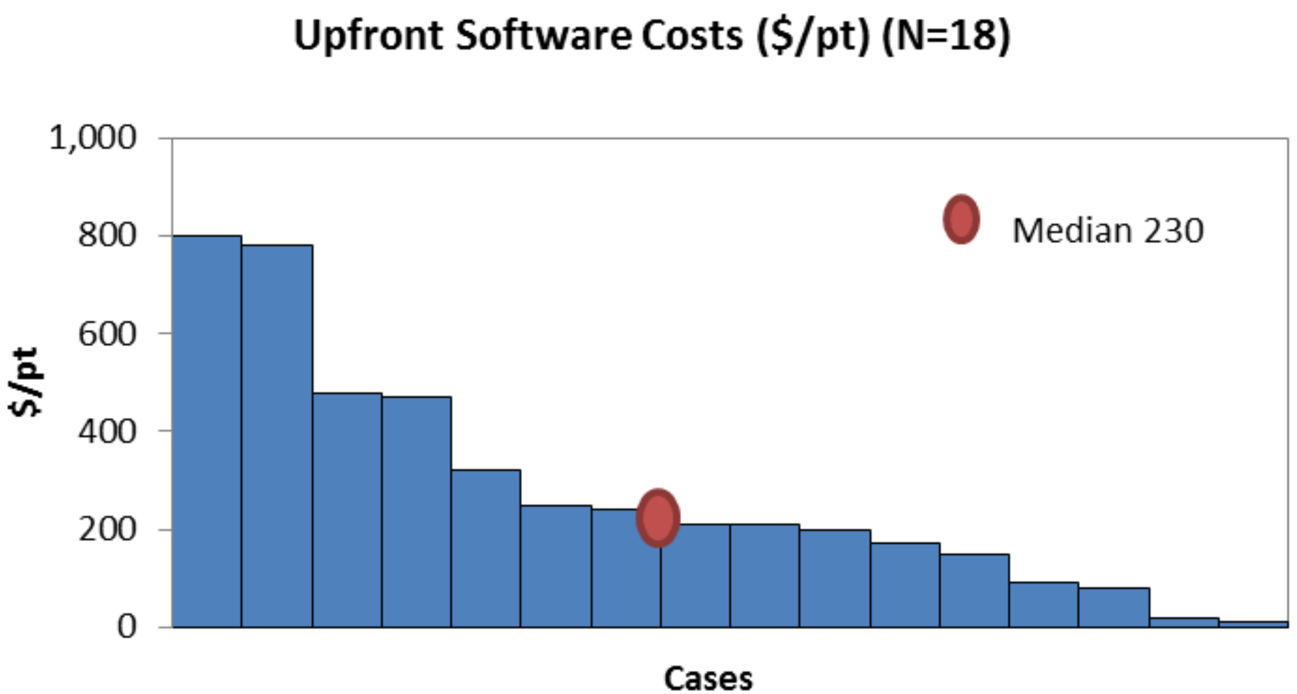
Type of Costs	Range			
	[$]	[$/pt]	[$/building]	[$/sf]
Upfront (N=18)	0 to 1,700-300,000	0 to 10-3,400	0 to 15-120,000	0 to 0.0008-0.77
Ongoing (N=17)	1,000-140,000	5-3,100	12-25,000	0.0004-0.15
5 yr ownership (N=14)	31,000-790,000	140-16,000	300-130,000	0.02-1.1

Type of Costs	Median			
	[$]	[$/pt]	[$/building]	[$/sf]
Upfront (N=18)	23,000	230	1,400	0.01
Ongoing (N=17)	16,000	200	400	0.01
5 yr ownership (N=14)	150,000	1,800	3,600	0.06

- Number of points
  - Range: 6-1,000
  - Median:200
- Number of buildings
  - Range: 1-560
  - Median:17
- Number of sf
  - Range: 0.2-22million
  - Median: 3 million

EIS Technology Costs

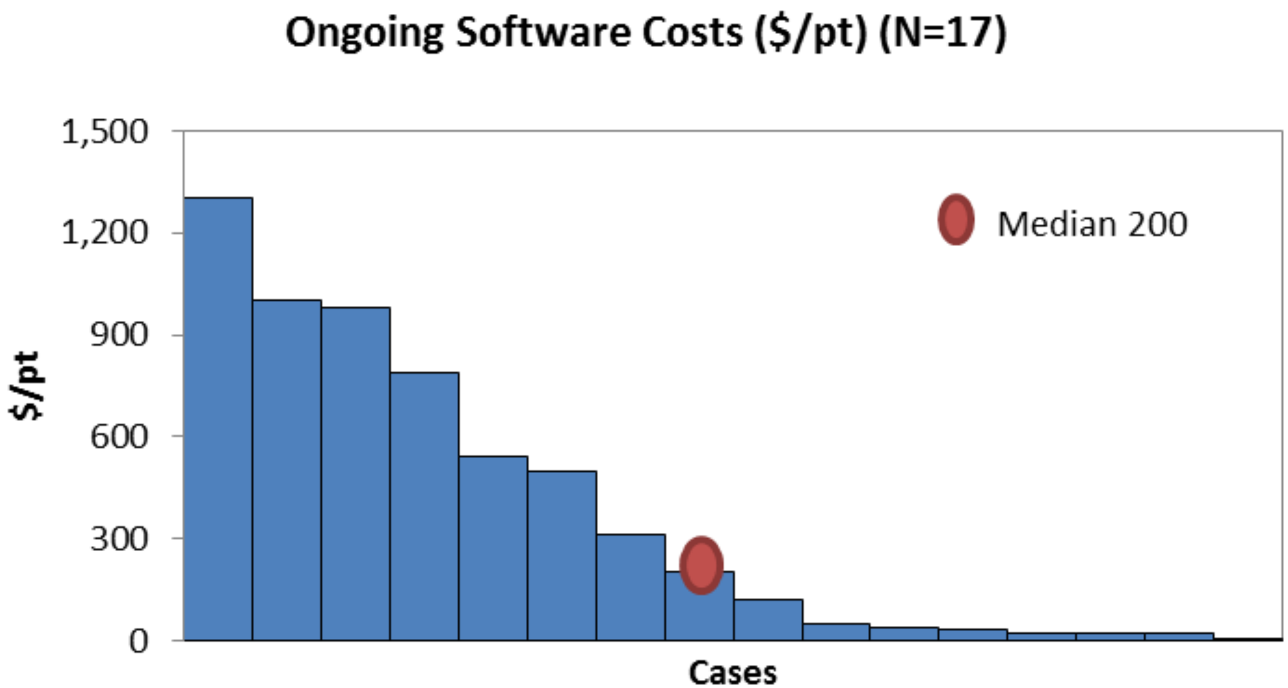
- Median upfront costs ~230$/pt, range is 2-3 orders magnitude across cohort



Not plotted but included in the calculation of median: 3400, 1700

EIS Technology Costs

- Median ongoing costs ~200 $/pt, range is 2-3 orders magnitude across cohort



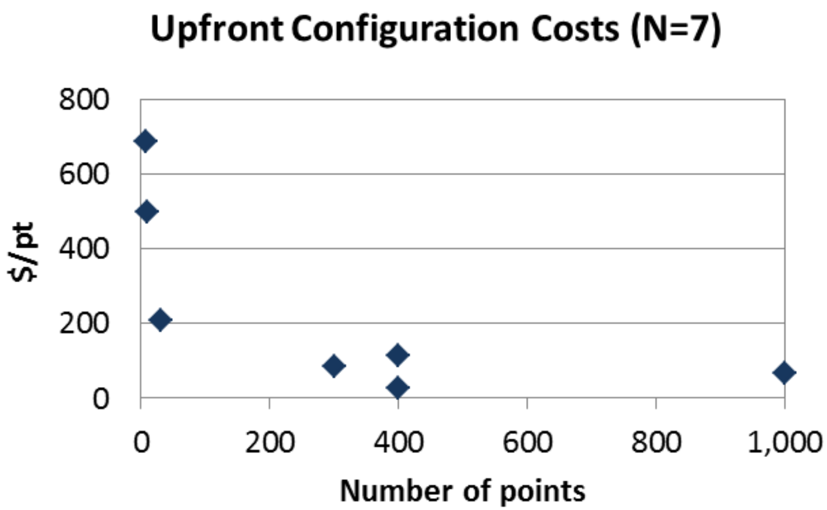
Not plotted but included in the calculation of median: 3100

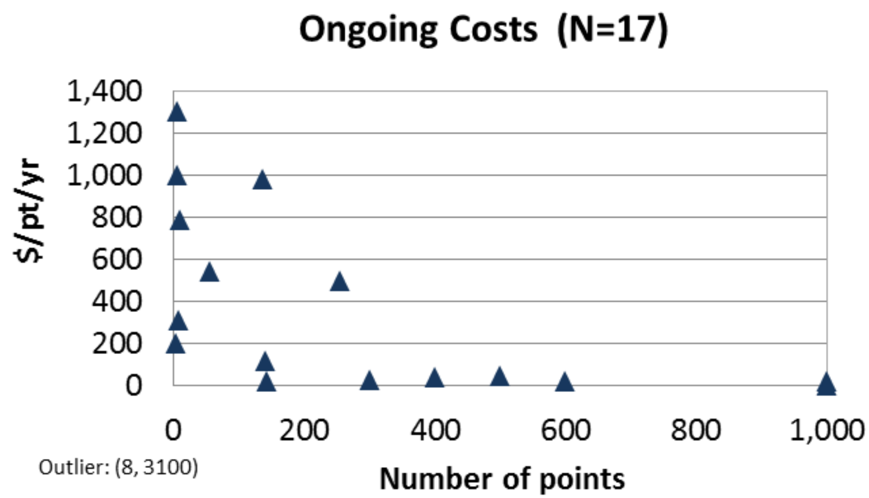
EIS Technology Costs

- What drives these large ranges in upfront and ongoing costs?
  - No effect due to on-premises vs SaaS delivery models
  - Economies of scale in $/pt as size of implementation increases (total #pts)
  - Diversity in vendor pricing models, market maturity and rapid evolution

EIS Technology Costs: Economies of Scale

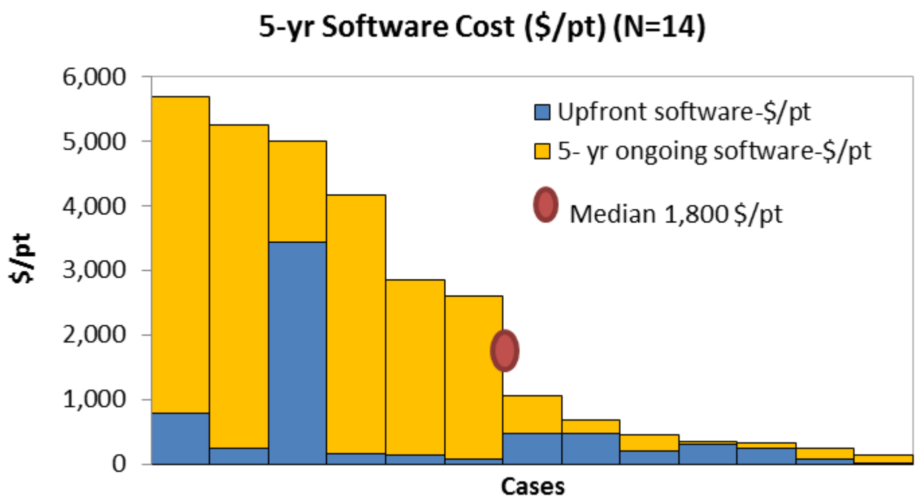
- $/pt decreases as number of points increases
  - Upfront configuration costs: 20-100$/pt plateau
  - Ongoing costs: 5-50$/pt plateau





EIS Technology Costs: Total Cost of Ownership

Extrapolation: Median 5-yr cost = $150K, 1800$/pt, .06$/sf



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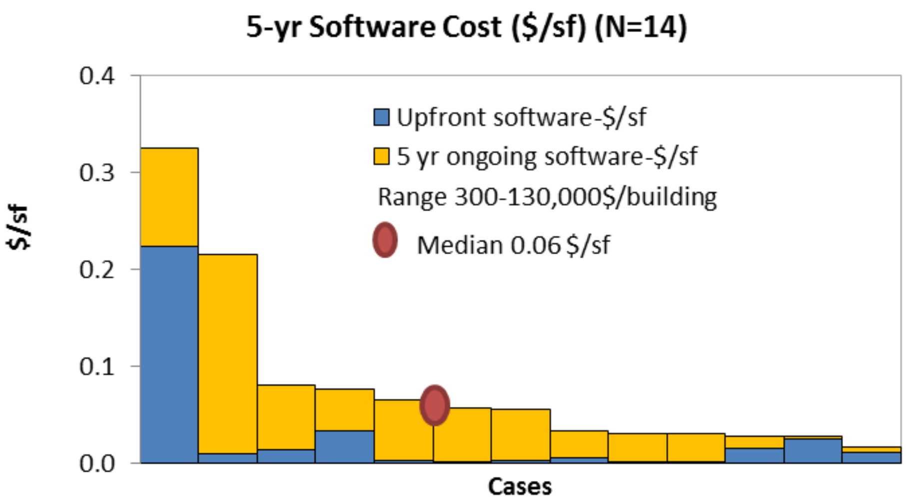

Not plotted but included in the calculation of median: 1.1

Payback on Investment in the EIS

- Extent of projects was most strongly correlated with achieved energy savings
  - Participants provided useful data on nature, scope, timing of projects,
  - Did not tend to have data on attributed savings or costs of projects
- Not many participants had conducted their own assessment of payback for their EIS deployment
- “Does a car mechanic quantify the value of their tools?”

Payback Examples from Study Participants

- 2 cases self-reported payback, and for 2 cases the R&D team was able to calculate a payback based on data collected

- < 2 years in 3 of 4 case instances, within the range reported in the literature
  - Case 1 – 3.4 year payback for 2 buildings 4.3 for another
  - Case 2 – 1.2 years for full campus deployment
  - Case 3 – <1 month due to non-energy savings, streamlining of personnel bill payment
  - Case 4 – <2 months

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Conclusions: Value of EIS

- Median building and portfolio savings of 17% and 8% would not be possible without use of the EIS
  - Median building and portfolio utility savings of $56K, and $1.3M

- Key Benefits
  - Operational efficiency, utility validation and payment, data/info for other processes and analyses

- Median 5-yr cost of software ownership, $150K, $1800/pt, .06$/sf, median number of points = 200
  - Large range in costs, some economies of scale with number of points
  - Commonly, ongoing costs assessed annually, per-building or -portfolio

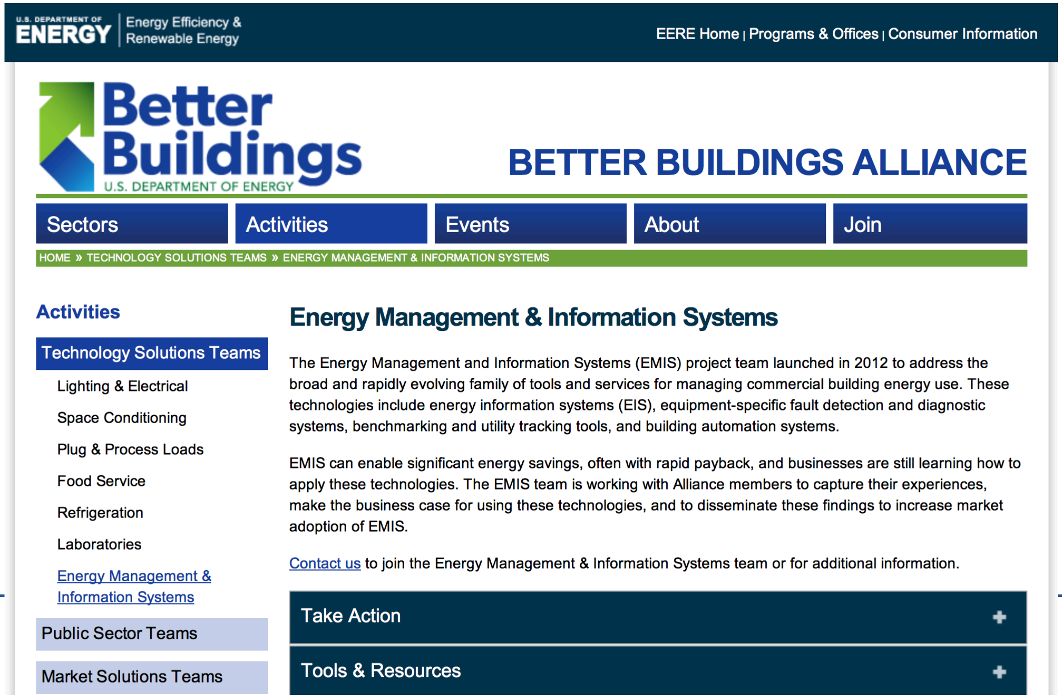
- Payback of the EIS not typically tracked by participants, however
  - In 3 of 4 cases, payback was less than two years
  - Consistent with reported findings in the literature

Conclusions: Key Factors and Best Practices

- Extent of efficiency projects and initial EUI most correlated with deeper achieved energy savings
- Depth of metering and years of EIS installation were next strongest factors, and pertain specifically to the EIS deployment
- Best practices
  - Installation of submetering, beyond whole-building level
  - Load profiling on a regular basis
  - Use of automated energy anomaly detection features
  - Monitoring peak load and managing demand charges
  - With regular usage over time, savings can accrue and deepen

Next Steps

- Conversion of technical findings into business case brochure or fact sheet
- Report and slides will be available from
  - LBNL website: eis.lbl.gov
  - DOE Better Buildings Alliance EMIS Project Team website via http://www4.eere.energy.gov/alliance/



Project Team Next Steps

- Next month the BBA EMIS Project Team will launch regular calls for our FY14 activities
- BBA members, please join us to kick off, and participate in a crash course on successful EIS use, including a synthesis of existing resources from the public domain

Complementary BBA Activity: Wireless Submetering Challenge

- In the EIS study cohort, submetering was associated with deeper energy savings
- Submetering is not common, costs are one barrier
- DOE is currently working with manufacturers to reduce costs of panel-level submetering from $1K/pt-->$100/pt
- The challenge model: DOE sets stretch spec, induces industry to meet spec by marshaling market demand
- Opportunities for commercial sector
  - Sign your support
  - Review the specification
  - Demonstrate the technology

http://www4.eere.energy.gov/alliance/activities/technology-solutions-teams/wireless-meter-challenge

THANK YOU

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Back-up Slides

Calculation of Utility Cost Savings

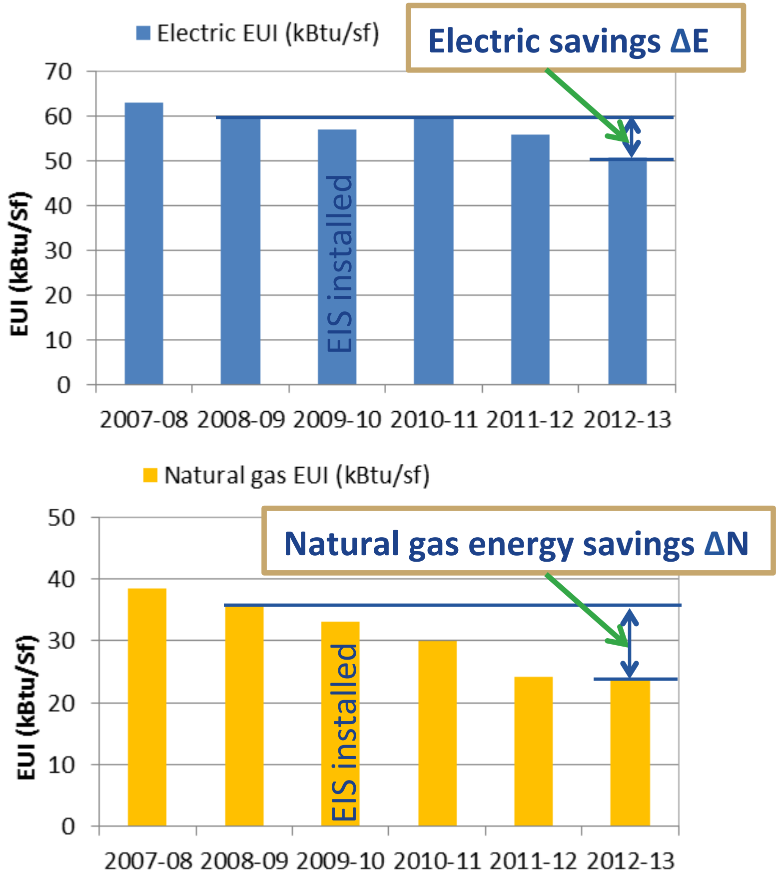
- Three-step process

  1. Calculated electric and natural gas energy savings for each site/portfolio

  2. Calculated utility cost savings for each site/portfolio
     - $\textit{Cost Savings} = \Delta E \times sf \times \$/Btu^{1} + \Delta N \times sf \times \$/Btu^{2}$

  3. Summarized median building and portfolio utility cost savings

Year-by-Year EUI Trend



Note: [1]2012 US average electricity price in commercial sector; [2]2012 US natural gas price in commercial sector –EIA, Electricity/natural gas monthly update, August 2013

Definition of Metrics

- Energy savings
  - the difference in EUI (kBtu/sf) between the most recent year, and the year before EIS installation
- Extent of projects
  - high = cases that conducted commissioning of HVAC systems, or that implemented projects that included both lighting and HVAC end uses
  - low = all other cases
- EUI prior to EIS installation
  - high = the EUI was higher than the national average as reported in [EIA 2003]
  - low = the EUI was lower than the national average
- Depth of metering
  - high = presence of sub-metering and/or integration of trend logs from the building automation system
  - low = campus-level or whole-building metering only

Definition of Metrics

- Total years since EIS installed
  - high = total years since EIS installed was higher than the median for the cohort of cases
  - low = total years since EIS installed was below the median
- User engagement
  - high= the reported person-hours per month was higher than the median for the cohort of cases
  - low = personal-hours per month was below the median
- User empowerment
  - high= responses “1” (immediately) when asked on scale 1-3, how quickly they could take action based on insights gained through use of the EIS
  - low = responses “2 or 3”

Wilcoxon-Mann Whitney and Effect Size

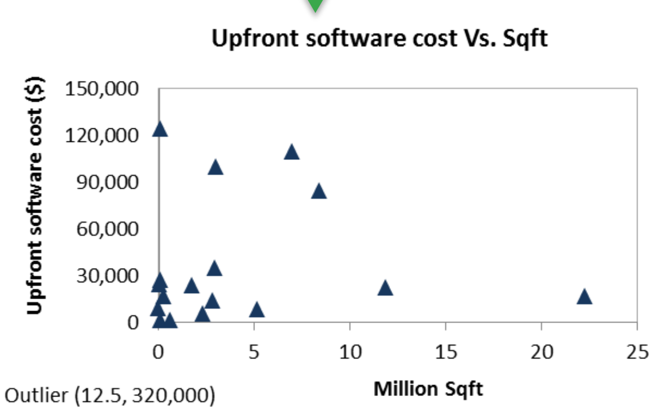
- WMW test [Mann & Whitney, 1947]
  - a nonparametric test comparing the median of two groups
  - does not assume the samples is normally distributed
- Effect size of WMW test [Field 2009, p550]

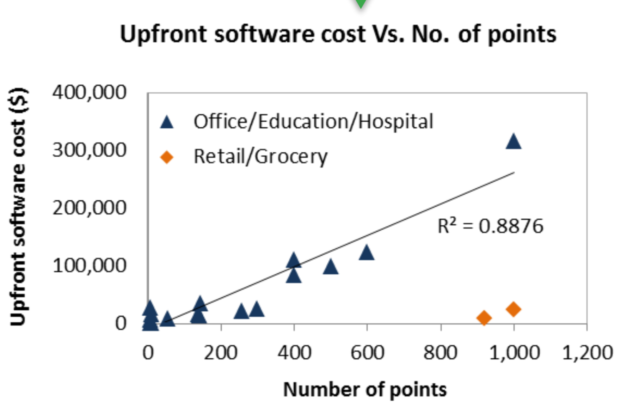
$$r = \frac{z}{\sqrt{N}}$$

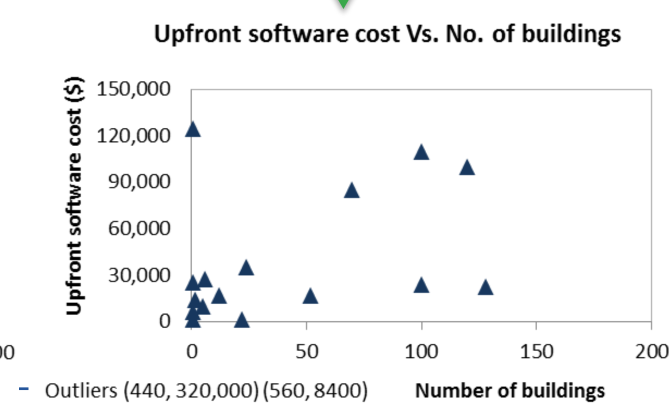
  - r – Effect size estimate; r>0.5, large effect size; 0.5>r>0.3, medium effect size; 0.3>r>0.1, small effect size;
  - z – z value obtained from performing the WMW test
  - N – Sample size of the study

Definition of Point

- "Points" are mostly WB and submetered electric and gas data points in our study
- Number of points used as a 'normalizing' common denominator
  - For software, # of points hosted and maintained is the 'service/product', as opposed to of the number of sites or sf covered
  - Upfront costs ~linear w number of points, not the number of buildings or sqft

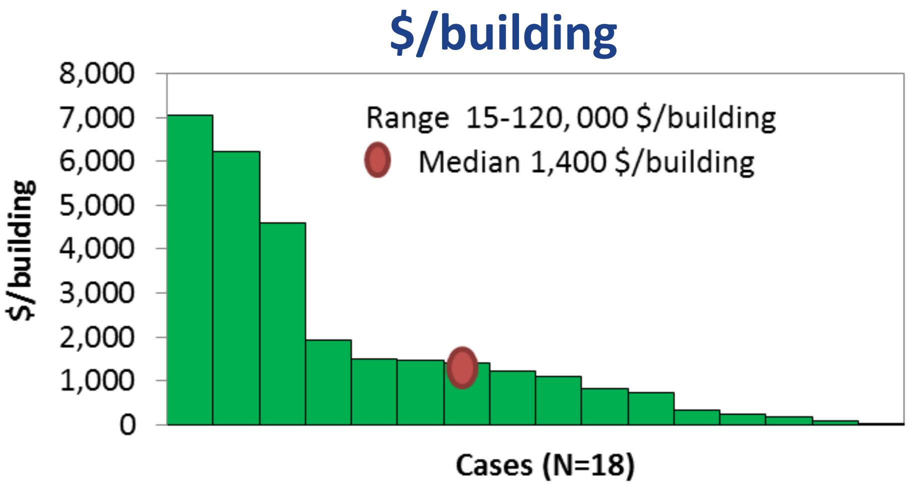




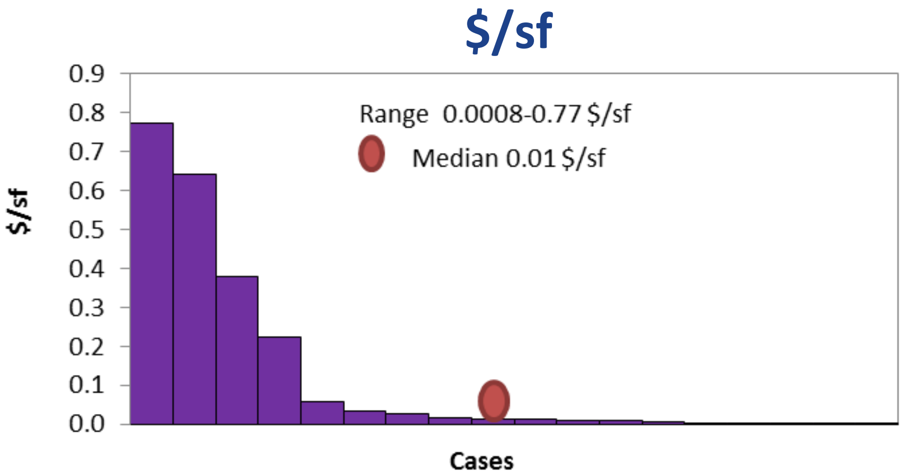


EIS Upfront Software Costs

- Median upfront costs ~1,400$/building, 0.01$/sf
- Range is 3-5 orders magnitude across cohort

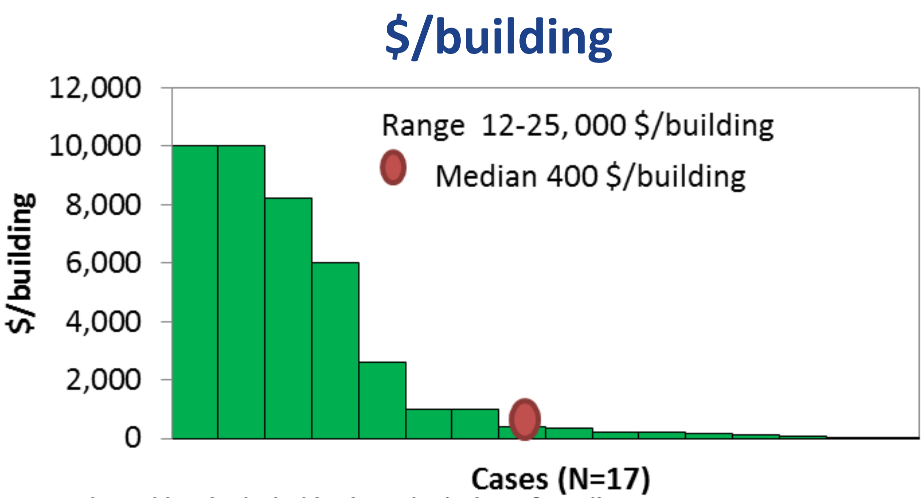


Not plotted but included in the calculation of median: 120,000, 25,000

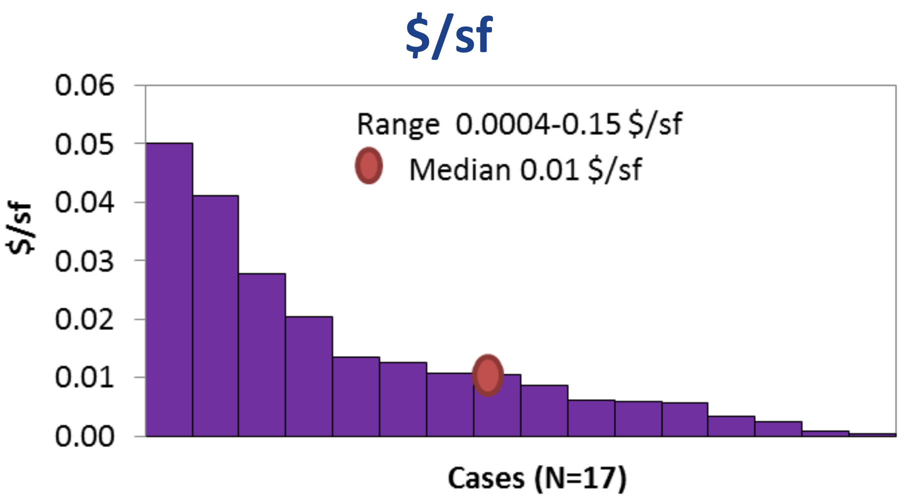


EIS Ongoing Software Costs

- Median ongoing costs ~400$/building, 0.01$/sf
- Range is 3-4 orders magnitude across cohort



Not plotted but included in the calculation of median: 25,000

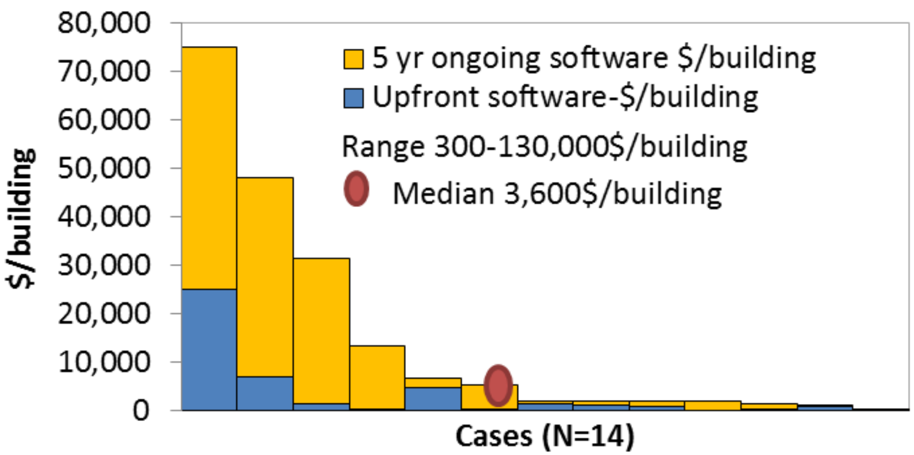


Not plotted but included in the calculation of median: 0.15

EIS Technology Costs: Total Cost of Ownership

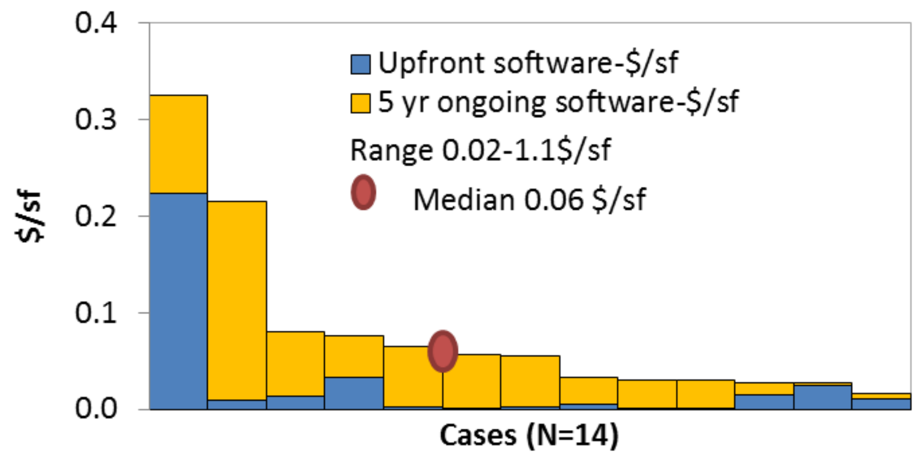
Extrapolation: Median 5-yr cost of Ownership 3600$/building, 0.06$/sf

$/building



Not plotted but included in the calculation of median:130,000

$/sf



Not plotted but included in the calculation of median: 1.1